Micro-fabricated Ion Energy Analyzer*

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-M. Blain, J. Stevens, J. Woodworth, APL 75 (1999) 3923;
-M. Sowa, M. Blain, R. Jarecki, J. Stevens, APL 80 (2002) 932.
-P. Kraus, T. Chua, C. Olsen, T. Bauer, IEEE-NANO-2004 (Munich,Aug17-19,2004).
-P. Kraus, T. Chua, et. al., 205th Meeting ECS (San Antonio, TX, May9-13, 2004).

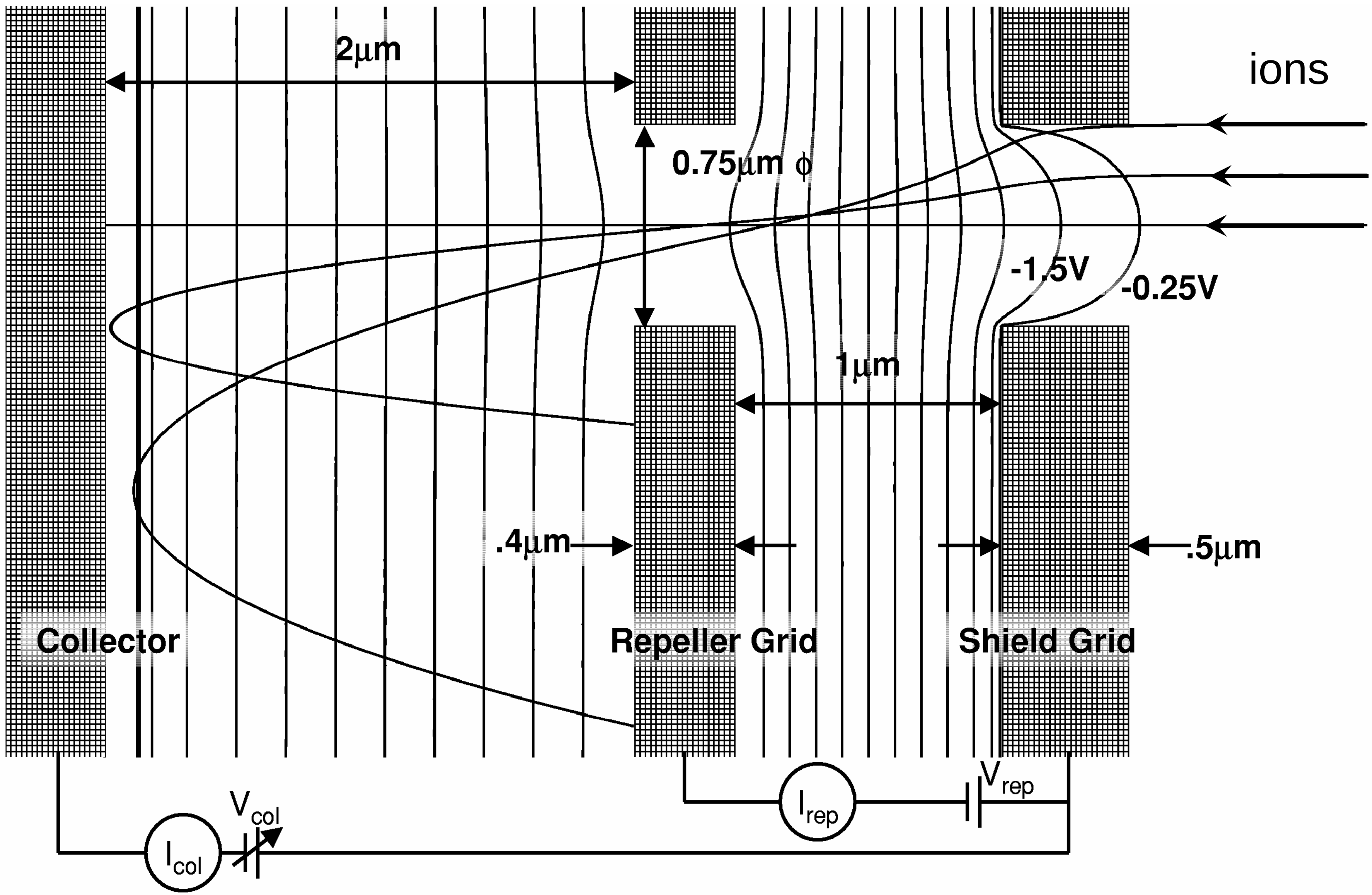
***Work partially supported by SEMATECH**

Goal: develop an ion diagnostic for plasmas used in semiconductor processing.

Why Micro-fabricate Ion Energy Analyzer?

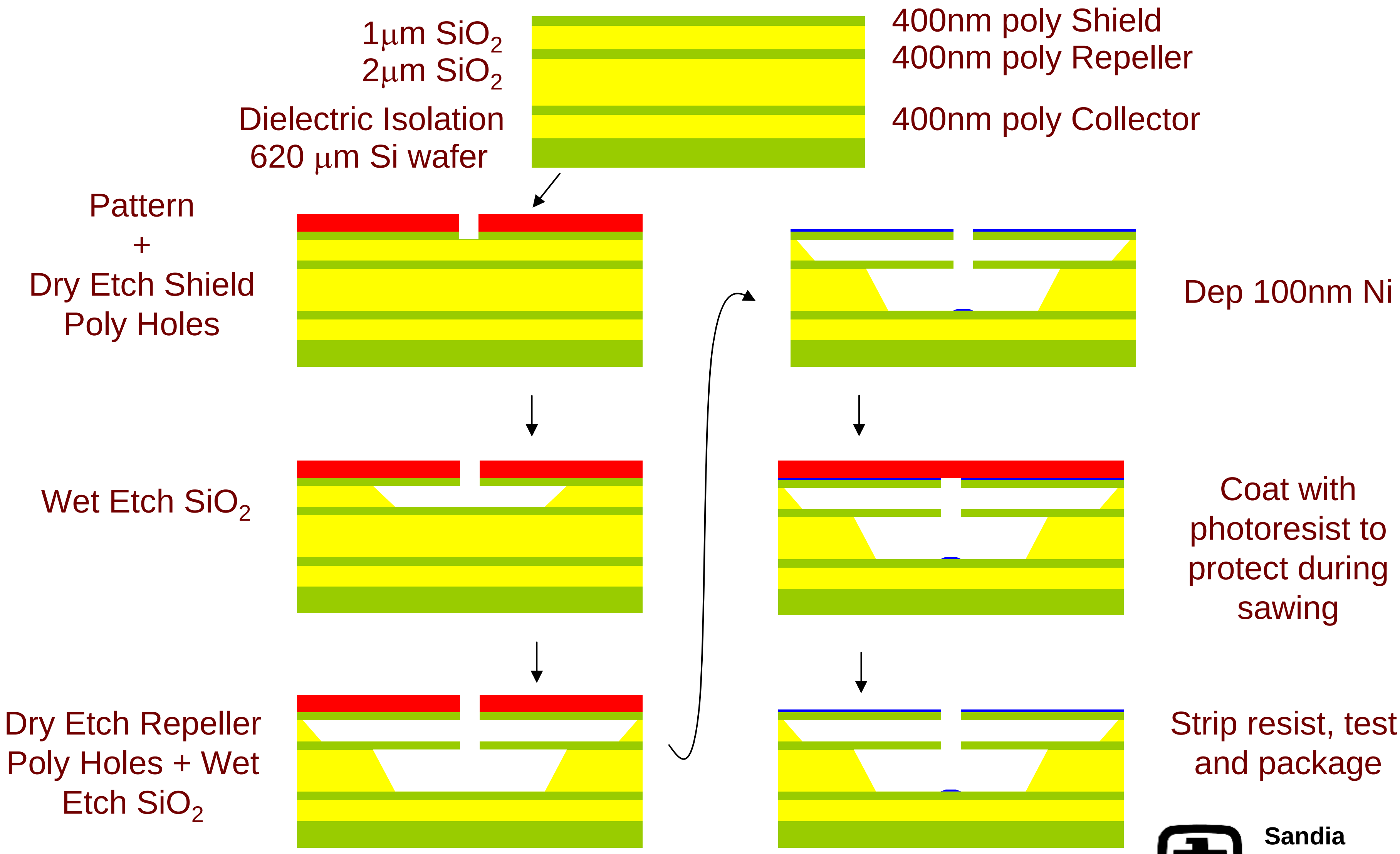
- Small size (can be put on top of a Si wafer)
- Nearly ideal hole alignment
- Very few ion - neutral collisions
- Good energy resolution in theory (~0.2%)

modeling

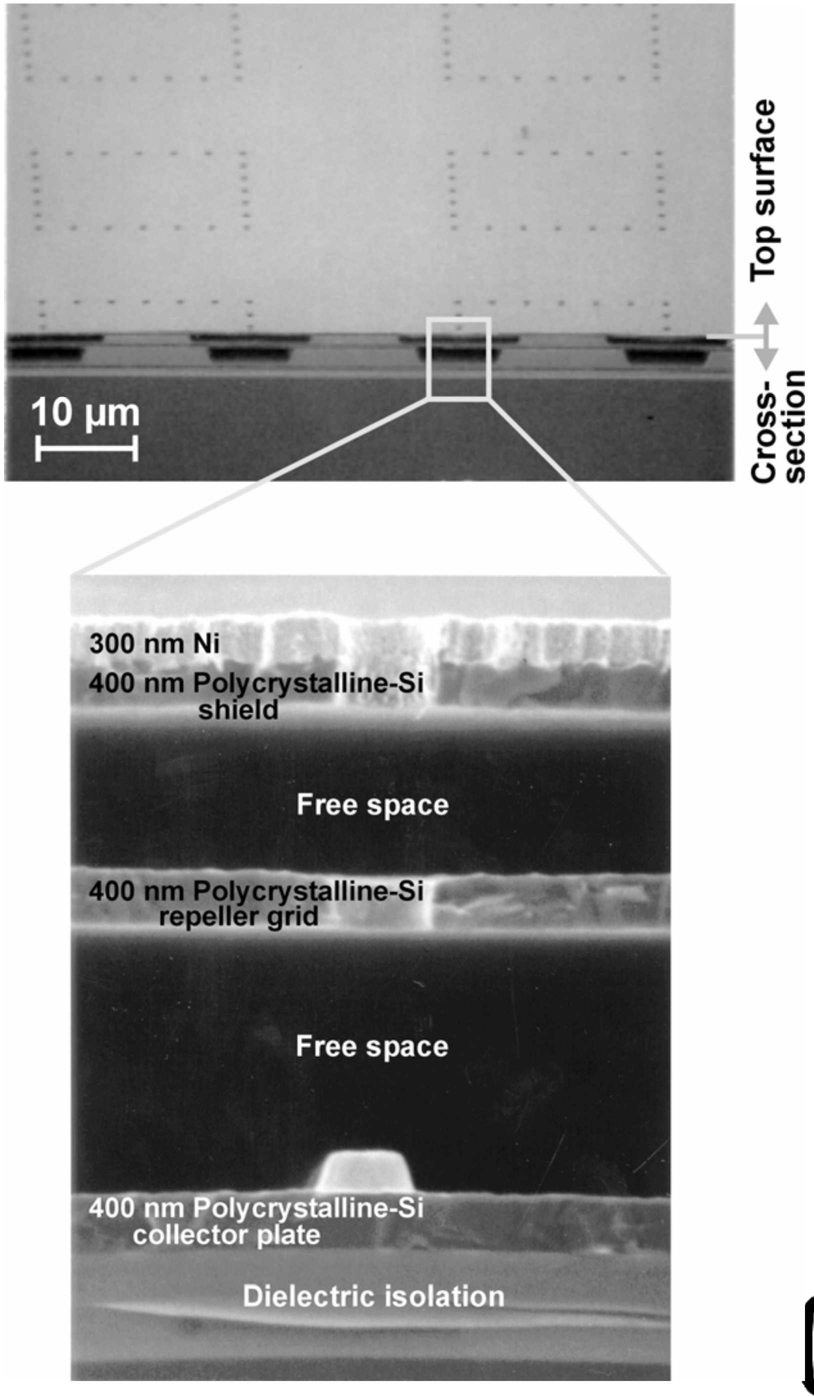


Typically there is 1 ion at a time in the analyzer.
The collector should be able to resolve ion energy differences of <1% at 50eV.

Energy Analyzer Fabrication

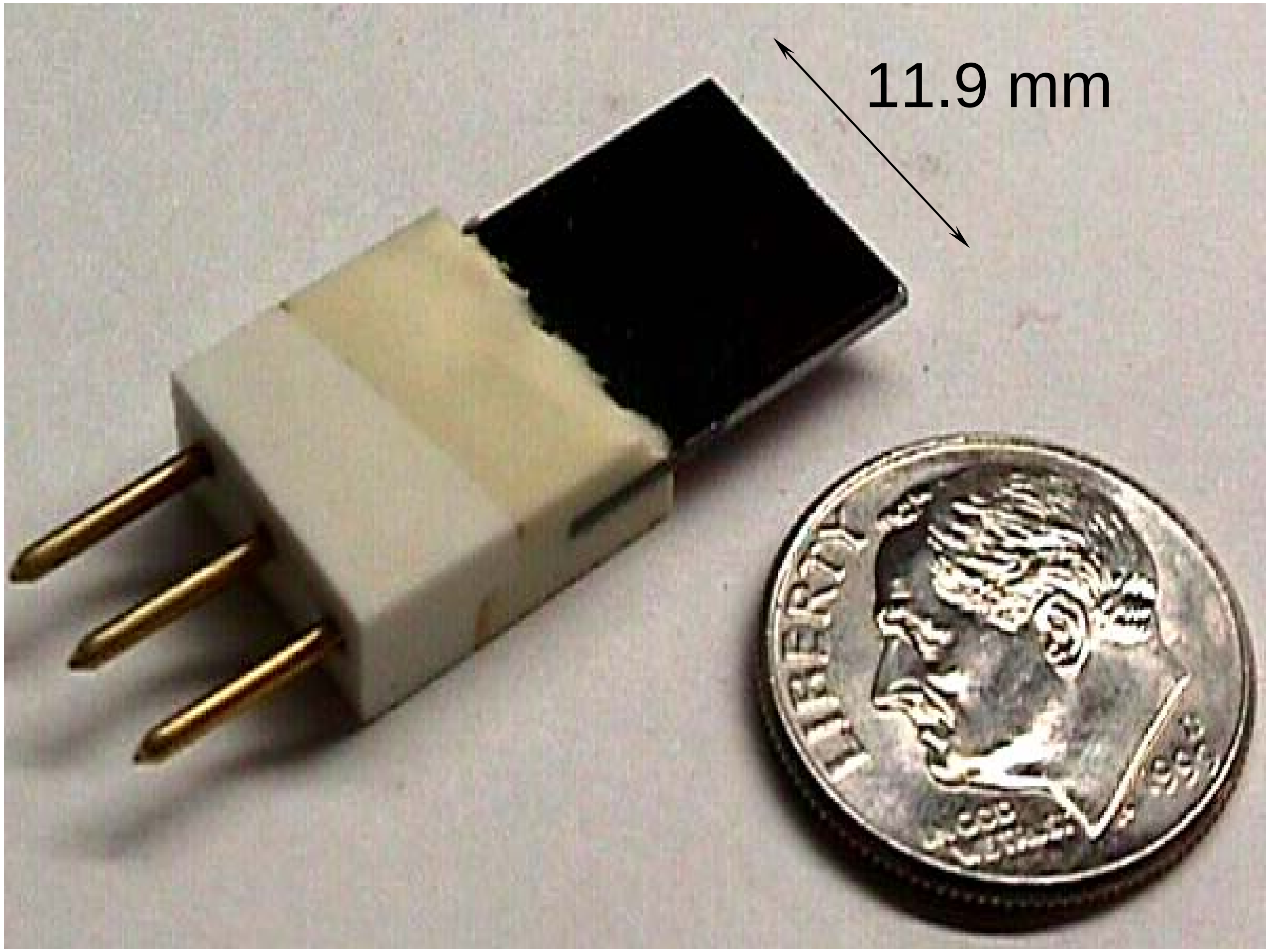


SEM Images of IEA

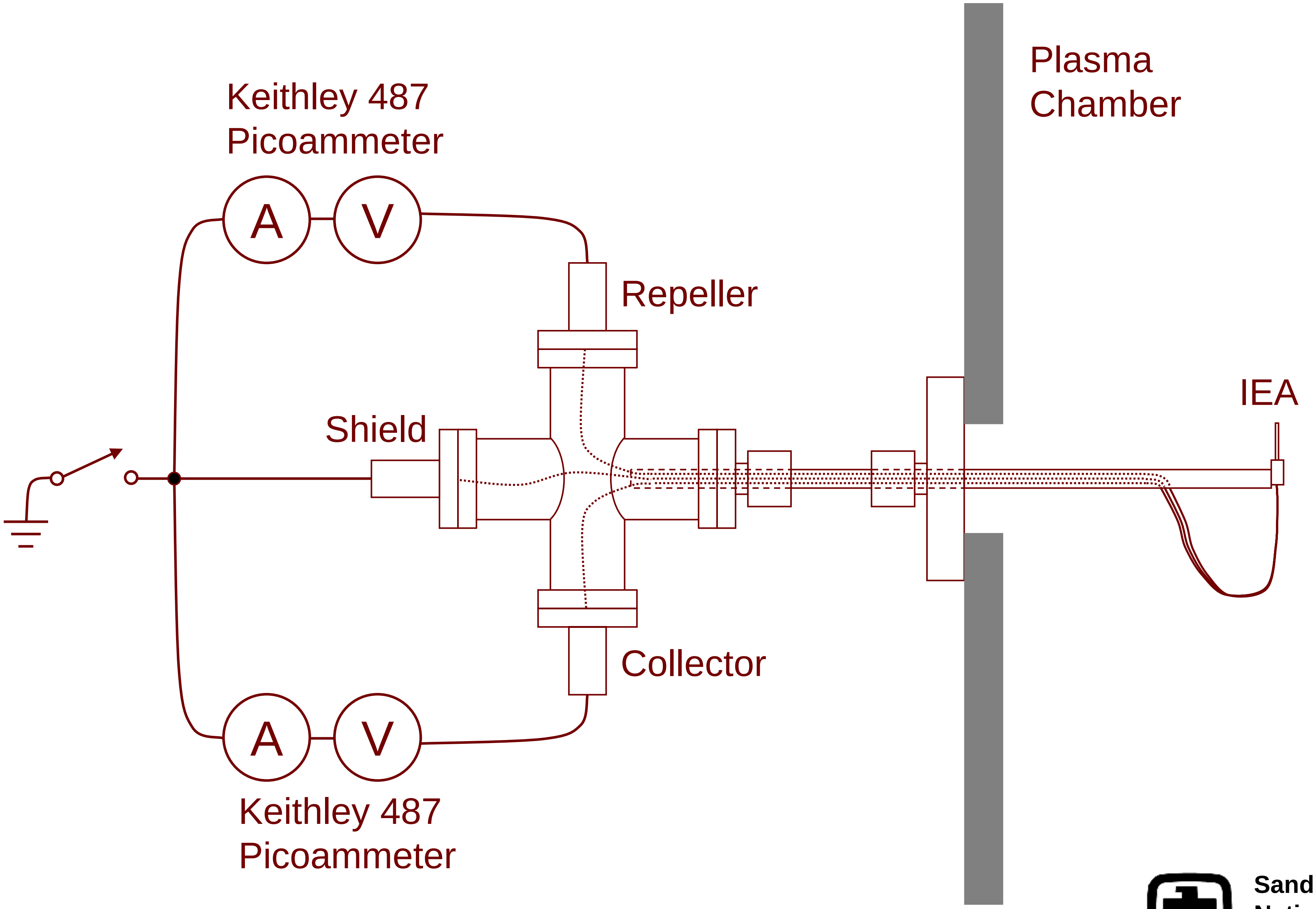


- 670,000 holes
- 0.5% open area

Finished IEA



Experimental Setup



Experimental Setup on Test Stand

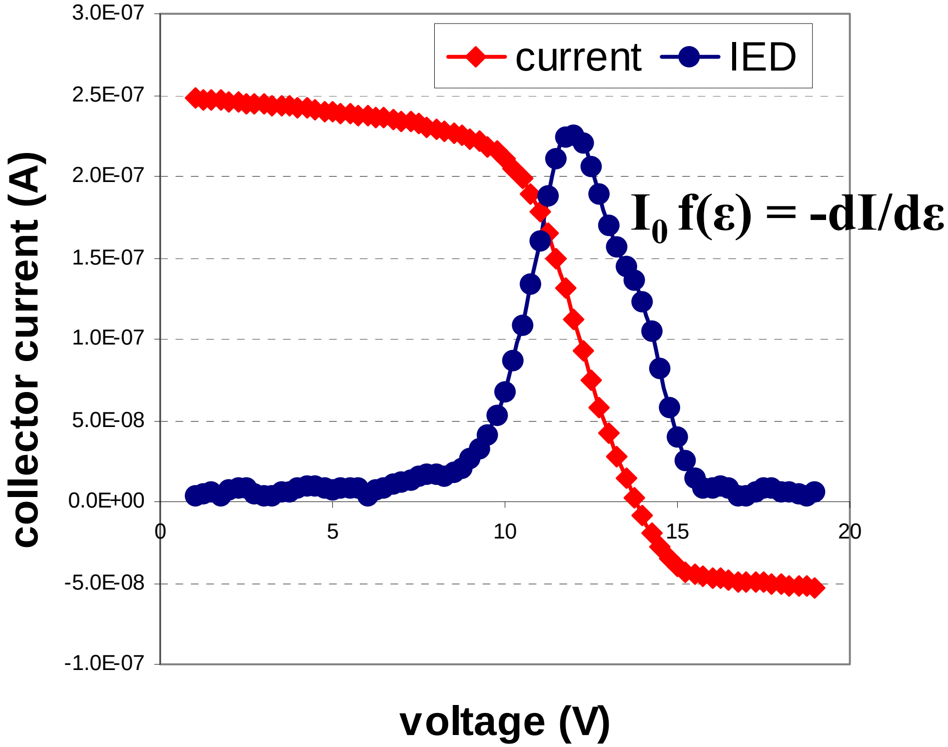
Collector current & IED vs. voltage

__Process conditions:__

150 W RF power

10 mTorr N_2

Inductively coupled plasma



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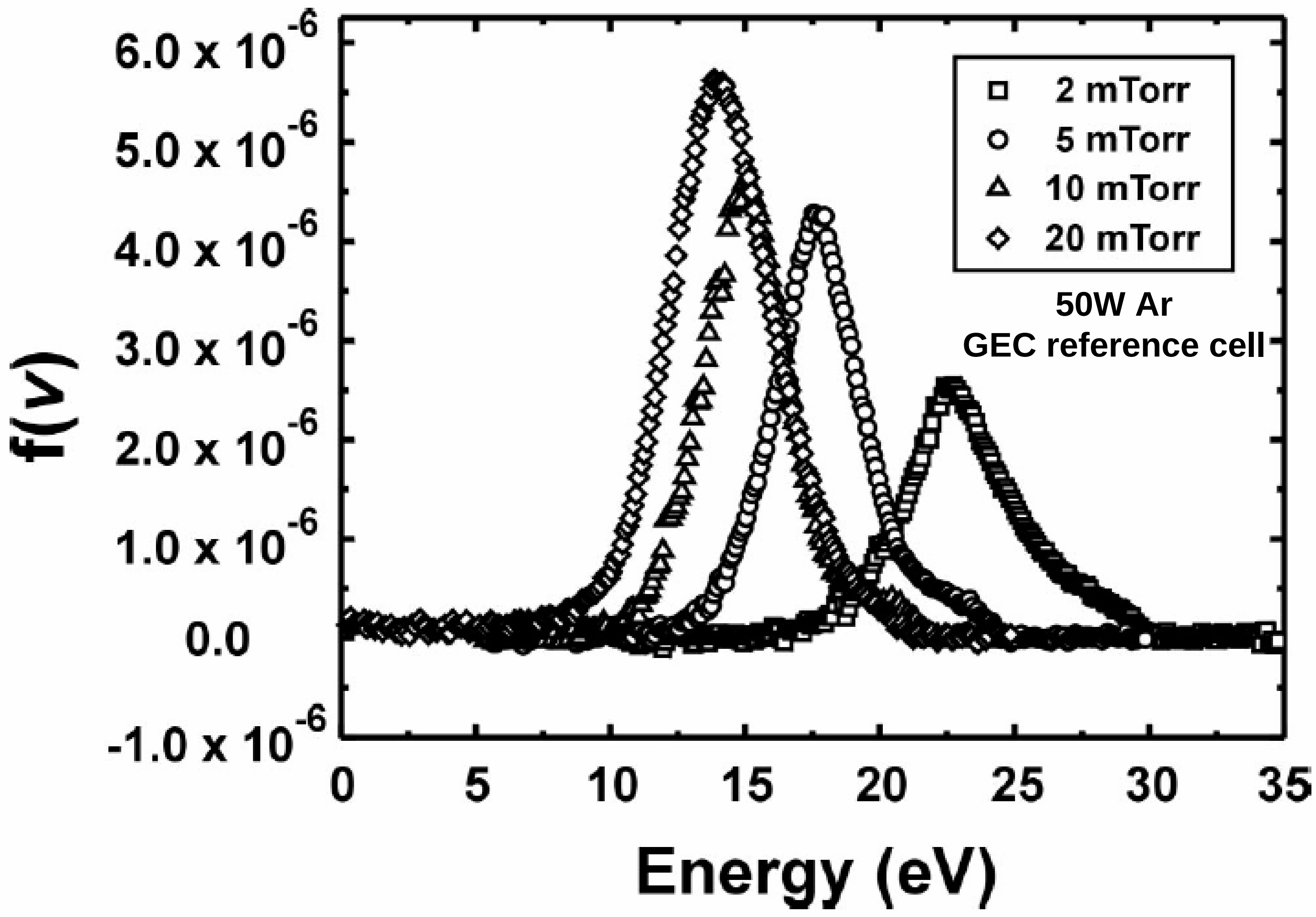
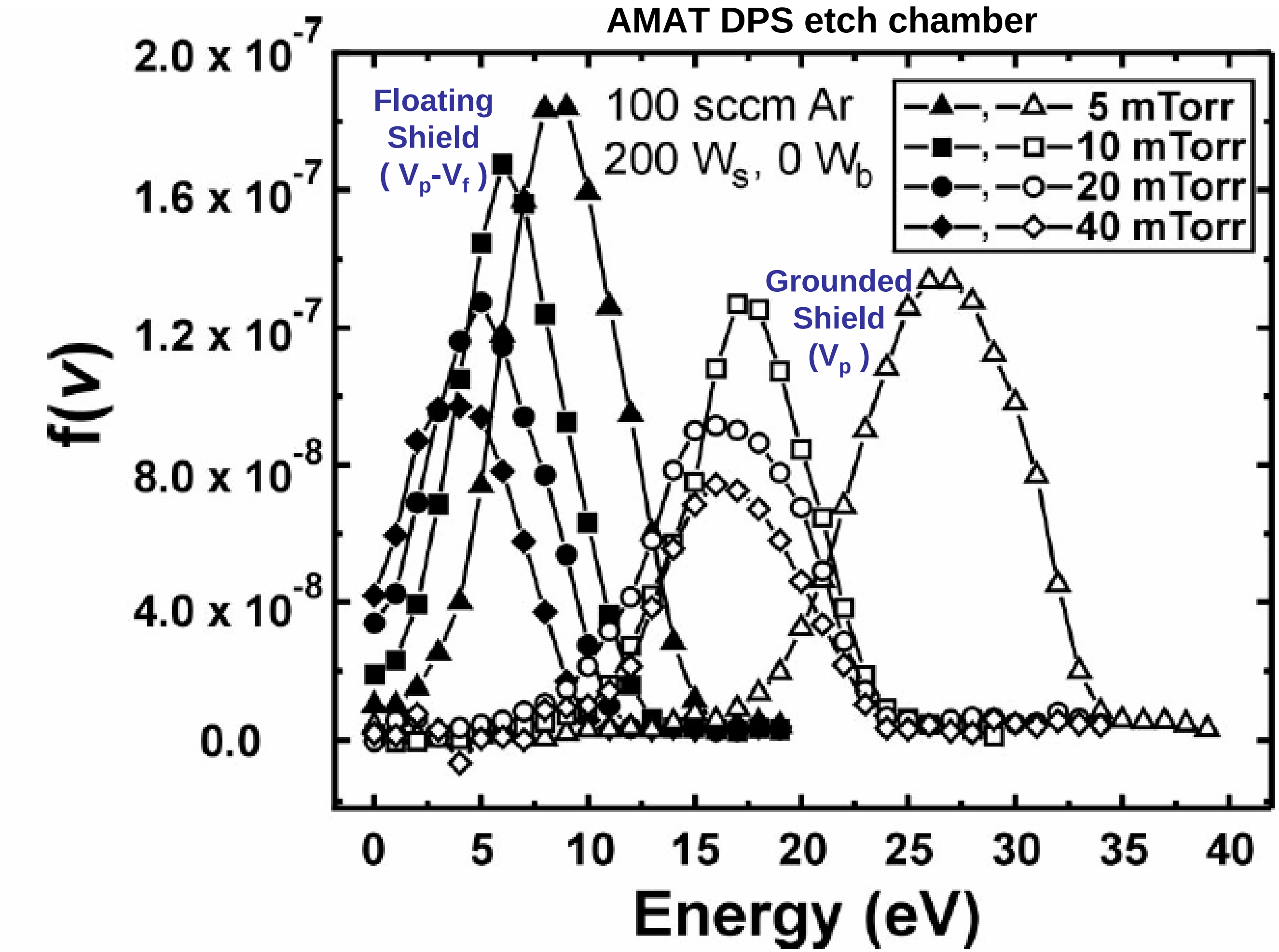
Ion energy distribution vs. pressure



Ion energy distribution vs. pressure



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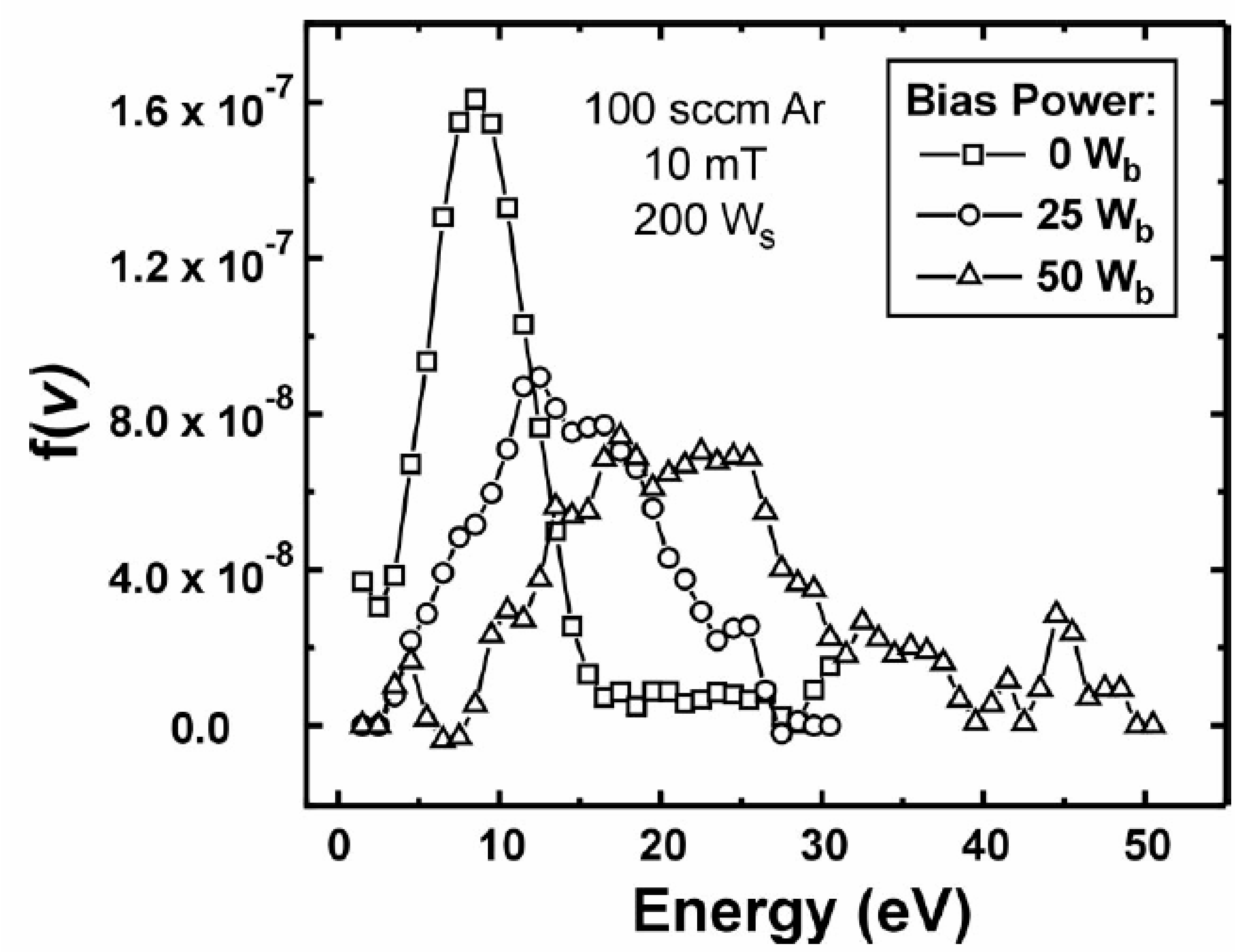
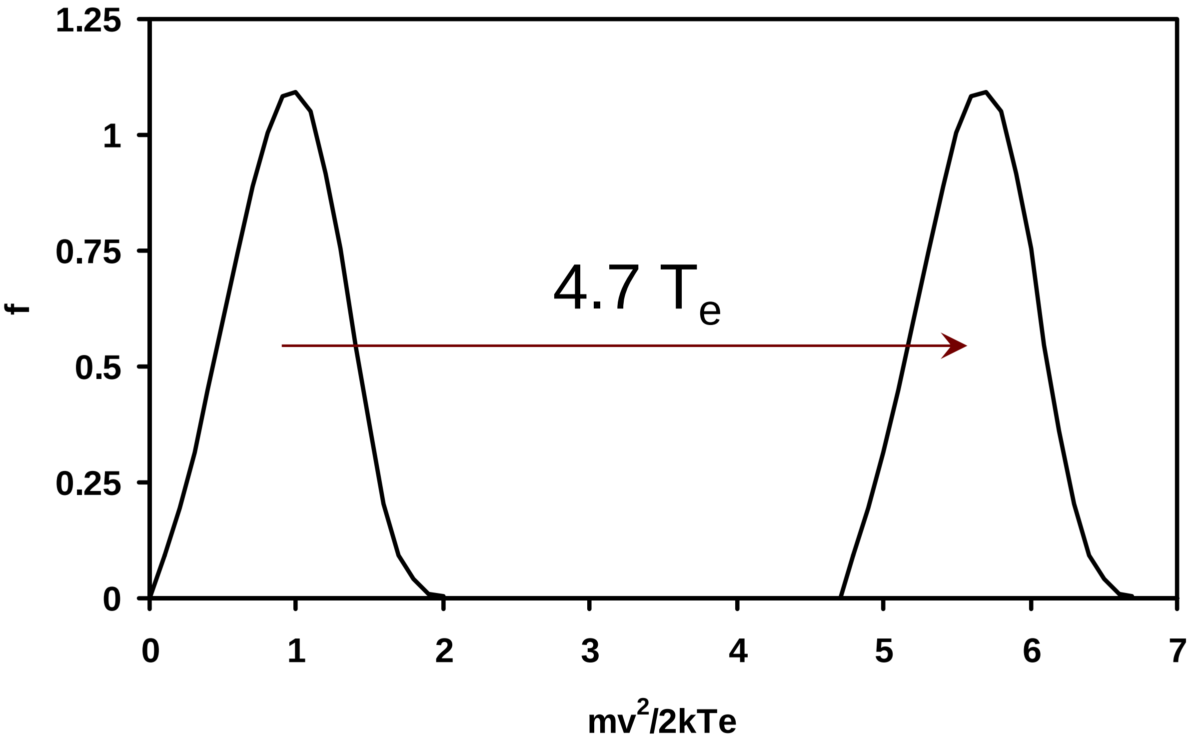
Ion energy distribution vs. RF bias

AMAT DPS etch chamber

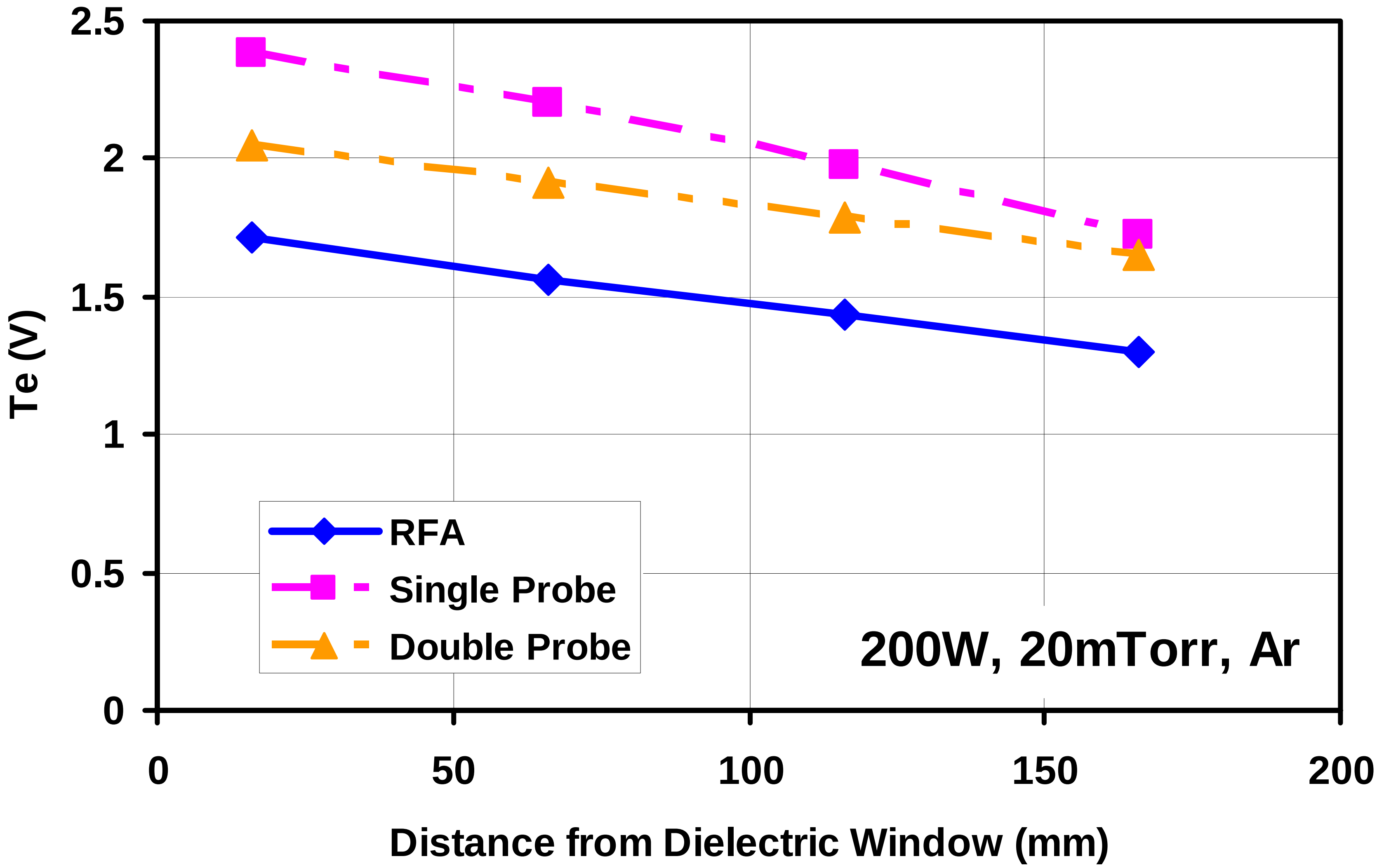


Inferred T_e from I.E.D.

- Model assumes that the ion energy distribution is developed in the presheath, then ions are uniformly accelerated across a collisionless sheath. [K.U. Riemann, Phys Fluids 24(12), 1981.]
- Peak ion energy predicted at 5.7 T_e.



T_e from IEA vs. Langmuir probe



IED in a Pulsed Plasma

Bauer, et. al.

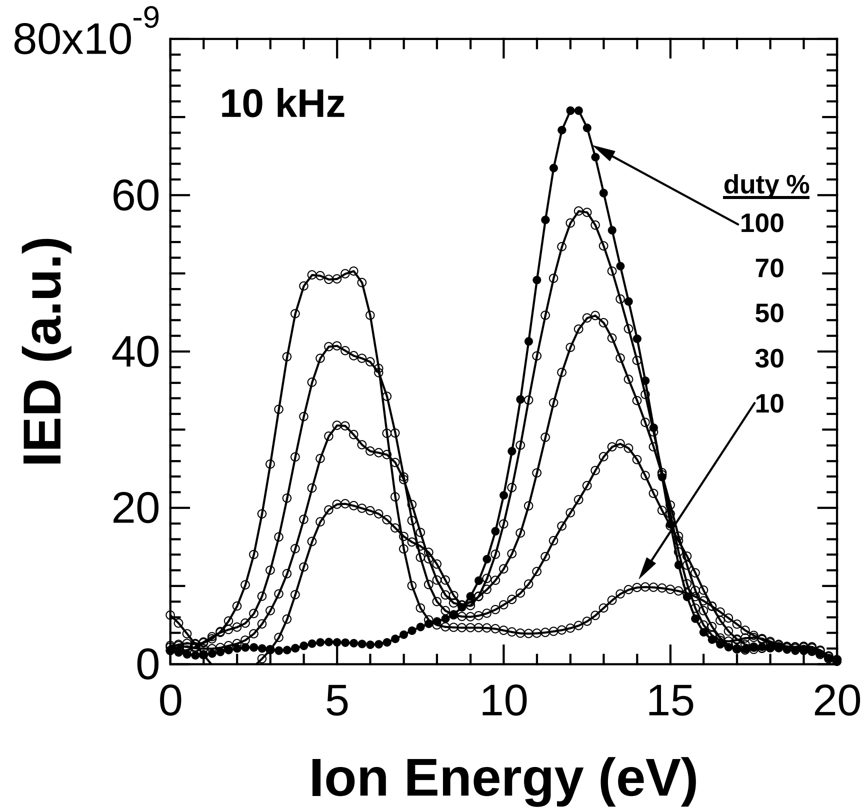
<u>Process conditions:</u>

Inductively coupled plasma source

10 kHz pulse rate, various duty cycles.

150 W time-averaged source power.

10 mTorr N_2



With reduced duty cycle, the population of high-energy ions decreases and low-energy ions increases.

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Conclusions and Comments

- The micro-fabricated IEA worked as expected.
- Ion energy distribution is determined by the presheath.
- T_e trends agreed qualitatively with Langmuir probes.
- Fabrication used standard MEMS operations, although we did not use the standard SUMMiT™ lot flow.
- It took several iterations to correct process and operational issues. There are 7 mask levels and ~120 process steps.
- Packaging is important. The goal was for the IEA to be a plug-in part. A lot of time was spent on making holders, epoxy packages, and improving leads.

General Comments for the MDL Facility

- MDL processes are rigorously controlled, for delivery of radiation hard IC's and MEMS parts.
  - You get what you ask for.
  - With 10's of products in the line at a given time, it is important that they don't affect each other.
- Material choices must be compatible with silicon CMOS.
  - Conductors: Al, W, Ti, TiN, poly-Si
  - Insulators: SiO_2, SiN, AlN, SiON
  - Other materials (Ni, Au, Pt) available at post processing.
- There are limitations on device size and thickness.

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